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NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-50

U.S. Geological Survey
Department of the Interior

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 50
July 1966

Dr. Peter C. Badgley
Chief, National Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D. C. 20546

Dear Peter:

Transmitted herewith are 2 copies of:

TECHNICAL LETTER NASA-50

A PRELIMINARY EVALUATION OF AIRBORNE

AND SPACEBORNE REMOTE SENSING DATA FOR HYDROLOGIC USES

by

Charles J. Robinove

This report constitutes the final report on the portion of Contract No. R-09-020-009 that applies to the Hydrology Definition program. Additional technical letters on specific subjects may be forthcoming but they should be considered supplementary to this final report.

U. S. Government Agencies Only

Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*U.S. Geological Survey, Water Resources Division, Washington, D.C.

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-50

A PRELIMINARY EVALUATION OF AIRBORNE AND SPACEBORNE REMOTE SENSING DATA FOR HYDROLOGIC USES*

by

Charles J. Robinove

July 1966

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Prepared by the Geological Survey for the National Aeronautics and Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-009

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A Preliminary Evaluation of Airborne And Spaceborne Remote Sensing Data for Hydrologic Uses

by

Charles J. Robinove

Introduction

Technology and science are not always moving at the same pace; one is usually trying to catch up to the other. The technological development of remote-sensing instruments capable of providing data about the Earth and its resources is moving ahead of the ability of the scientific community to assimilate the data collected and to develop a facility to use the data to their best advantage. The U.S. Geological Survey, in fulfilling its responsibility to the public to investigate all means of improving its program of resource-data collecting has embarked upon a program of analysis of the data returns from airborne and spaceborne remote sensors to determine whether the data is of use in the field of hydrology and, as a sound product, what further data of significance in hydrology can feasibly be collected by remote sensors. This program is being conducted in cooperation with the National Aeronautics and Space Administration, Office of Space Science Applications, Earth Resources Survey Program, which is in charge of the development of spaceborne remote sensors for the disciplines of geology, hydrology, geography, cartography, agriculture, forestry, and oceanography.

The purpose of this report is to evaluate briefly the use of remote sensors in hydrology as of this time. Some sensors have already proved their value, some have been shown to be of little use in hydrology (although they may be of immense value in other disciplines), and some have not been evaluated because of a lack of data from the sensors or because hydrologists have not yet had an adequate opportunity to examine their usefulness. This progress report should, then, be considered a means of reporting to the hydrologic community on the status of remote sensors at the present time and on the present capability of hydrologists to assess the data, and not as a means of promoting the development of one type of sensor at the expense of others. Not until the capabilities and limitations of the sensors are proved will such a selection be possible.

Needs for Water-Resource Data

Water-resource data is needed both for research on the principles of occurrence, movement, and interactions of water, and as a basis

for planning the use and control of water. For the purpose of this report these data needs are grouped in the accompanying chart in seven major categories that cover, in a general manner, all the major needs. They are matched against the remote sensors that have received the most attention by hydrologists, and a brief evaluation of each one's usefulness is given. The use of remote sensors goes hand in hand with the needs for water-resource data -- neither can reach its maximum usefulness until models (conceptual, mathematical, or analog) are sufficiently developed to make proper use of the data. For example, modeling the distribution of pollutants in a tidal estuary for the purpose of predicting their concentration and distribution at any time cannot be accomplished until the analytical equations of diffusion and dispersion are fully developed and usable in actual situations in the field, not just in ideal cases. It is quite possible that remote-sensor data such as visible streamlines in water on a photograph or the thermal contrasts on the water surface as seen in an infrared image may be usable, or indeed vital, data. There is always the possibility, however, that the data may not be usable, so that different remote-sensing techniques will have to be developed for the purpose.

Relative value of remote sensors in hydrology

The chart includes only those sensors that have received some attention by hydrologists. A subjective ranking of the use of the sensors would place photography at the top because of the capability of hydrologists to use photography to great advantage at the present time and because of the easy interpretability and the lack of substantial data reduction needed for the use of photographs. For these reasons, we would recommend that top priority be given to photographic sensors in orbiting satellites for hydrologic surveying.

Infrared sensors, because of their capability of sensing thermal features, have a large potential in hydrology, but it is secondary to the potential of photographic systems. Problems of emissivity measurement hamper the use of infrared imagery for quantitative geohydrologic use, and the imagery may be best used for semiquantitative determinations of water-surface temperature.

Radar at present is best used for geologic purposes because, at the present state of the interpretive art, it does not provide direct hydrologic evidence. It does, however, provide much geologic information that can be interpreted in hydrologic terms.

Ultraviolet and microwave techniques have not been evaluated by hydrologists because so little data is available and basic research has not been done on the interactions of ultraviolet and microwave energy with features of hydrologic significance. From the state of the art in ultraviolet and microwave imaging, for example, it is our opinion that the resolution that could be achieved by the systems from orbital altitudes would be much too coarse for hydrologic

purposes, although it may well be satisfactory for oceanographic purposes where fine resolution can be sacrificed for areal coverage.

Future research needed

Future applications of remote sensors in hydrology depend on two factors: (1) the capability of instruments to collect data and (2) the capability of the hydrologic community to assimilate and use the data to best advantage. Common to both these factors is the need for an accelerated basic-research program to determine the types of data that can be collected and used. A single broad example may suffice to illustrate this point.

Studies of lakes have traditionally been made of individual lakes with the objectives of either (1) describing in detail the setting and dynamics of a particular lake or (2) elucidating a scientific principle, using a lake as a testing ground. It has been enormously difficult for the limnologist to collect and use data that have transfer value in describing a lake region or in categorizing lakes on the basis of other than geologic factors. Color photography from aircraft and spacecraft is capable of recording the shape and size of lakes and also the color of the water. Does the color of the water have a meaning in terms of the chemistry, biology, or sediment characteristics of a lake or group of lakes? If it is significant, then color photography may become a significant tool for the limnologist. In order to evaluate the use of color photography, however, it will be necessary to do research on the spectral reflectance and absorbance of lake waters and the associated hydrologic parameters. Only when such research is much farther along than at present can the limnologist interpret the color seen in photographs with confidence that he is assessing meaningful data.

Conclusion

At present remote sensors have a limited application in hydrology. An increase in the ability of hydrologists to interpret and use the data from well-developed sensors, coupled with an accelerated research program in the types of data needed from more exotic sensors, can provide maximum benefits from the blending of data collection and use.

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REMOTE-SENSOR SYSTEM	DATA AVAILABLE FROM REMOTE-SENSOR SYSTEM
PANCHROMATIC PHOTOGRAPHY	MUCH AIRCRAFT DATA TAKEN FOR MANY PURPOSES. SOME SPECIAL DATA. SOME SPACE DATA.
MULTISPECTRAL PHOTOGRAPHY	SOME EXPERIMENTAL AIRCRAFT DATA AVAILABLE, PRIMARILY 9-LENS PHOTOGRAPHY. BUT MUCH WORK HAS BEEN DONE WITH THE USE OF SPECIAL FILM-FILTER COMBINATIONS FOR SPECIFIC PURPOSES.
INFRARED PHOTOGRAPHY	MUCH AIRCRAFT DATA AVAILABLE.
COLOR PHOTOGRAPHY	MUCH AIRCRAFT AND GEMINI SPACECRAFT DATA.
INFRARED-COLOR PHOTOGRAPHY	AIRCRAFT DATA AVAILABLE.
INFRARED RADIOMETRY	DATA AVAILABLE FROM AIRCRAFT AND FROM TIROS AND NIMBUS SATELLITES.
INFRARED IMAGERY	DATA AVAILABLE FROM AIRCRAFT AND FROM TIROS AND NIMBUS SATELLITES.
RADAR IMAGERY	AIRCRAFT DATA AVAILABLE.

Approximate amount of data use:
Small -- small number of interpreters evaluating techniques
Moderate -- a few persons using techniques in specialized studies.
Large -- used by many hydrologists as a standard tool in hydrologic studies.

MEASUREMENT OF PHYSICAL CHARACTERISTICS OF WATER SURFACES	MEASUREMENT OF CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF WATER
LARGELY UNPROVED, WITH THE EXCEPTION OF THE ABILITY TO SENSE STREAMLINES ON WATER SURFACES THAT MAY BE INDICATIVE OF MOVEMENT OF POLLUTANTS OR OTHER EFFLUENTS. SMALL DATA USE.	USEFUL ONLY FOR ASSESSING SOME VEGETATION TYPES. SMALL DATA USE.
NOT USEFUL AT THE PRESENT TIME. SMALL DATA USE.	MAY BE VALUABLE AS A SUPPLEMENT TO OTHER PHOTOGRAPHY BUT SPECIFIC INTERPRETATION CRITERIA HAVE NOT BEEN DEVELOPED. SMALL DATA USE.
NOT USABLE BECAUSE WATER SURFACES ALWAYS APPEAR BLACK IN INFRARED PHOTOGRAPHY. NO DATA USE.	NOT USABLE BECAUSE WATER SURFACES ALWAYS APPEAR BLACK IN INFRARED PHOTOGRAPHY. NO DATA USE.
OF SOME VALUE BUT RIGOROUS EVALUATION HAS NOT BEEN MADE. SMALL DATA USE.	PROBABLY A HIGH POTENTIAL FOR USE BUT IT MUST BE SUPPORTED BY BASIC RESEARCH IN THE SPECTRAL RESPONSE OF WATERS OF VARIOUS TYPES. SMALL DATA USE.
MAY PROVIDE A HIGHER CONTRAST FOR MAPPING OF DISCONTINUITIES ON WATER SURFACES THAN ANY OTHER TYPE OF PHOTOGRAPHY. SMALL DATA USE.	PROBABLY NOT HELPFUL IN THE DETECTION AND IDENTIFICATION OF SUBSTANCES IN WATER BUT MAY BE USEFUL IN MAPPING THEIR DISTRIBUTION, WHICH IS ONE OF THE MOST IMPORTANT FACTORS. SMALL DATA USE.
VALUABLE FOR MEASUREMENT OF WATER-SURFACE TEMPERATURE BUT WILL NOT ACHIEVE ITS GREATEST POTENTIAL UNTIL THERE IS FULL DEVELOPMENT OF ANALYTICAL EQUATIONS THAT EXPRESS THE TEMPERATURE DISTRIBUTION WITHIN A WATER BODY AS A FUNCTION OF THE SURFACE TEMPERATURE. MODERATE DATA USE.	VALUABLE ONLY IF THE CHEMICAL OR BIOLOGICAL FACTORS HAVE AN EFFECT ON THE TEMPERATURE OR EMISSIVITY OF THE WATER SURFACE. SMALL DATA USE.
VALUABLE FOR MEASUREMENT OF WATER-SURFACE TEMPERATURE OVER LARGE AREAS BUT WILL NOT ACHIEVE ITS GREATEST POTENTIAL UNTIL THERE IS FULL DEVELOPMENT OF ANALYTICAL EQUATIONS THAT EXPRESS THE TEMPERATURE DISTRIBUTION WITHIN A WATER BODY AS A FUNCTION OF THE SURFACE TEMPERATURE. SMALL DATA USE.	VALUABLE ONLY IF THE CHEMICAL OR BIOLOGICAL FACTORS HAVE AN EFFECT ON THE TEMPERATURE OR EMISSIVITY OF THE WATER SURFACE. SMALL DATA USE.
WATER IS AN EXCELLENT REFLECTOR OF MICROWAVES AND, THEREFORE, WATER SURFACES SHOW AS A UNIFORM BLACK TONE ON RADAR IMAGERY. RADAR IMAGERY, THEREFORE, IS OF NO VALUE IN MEASURING PHYSICAL, CHEMICAL, OR BIOLOGICAL CHARACTERISTICS OF WATER. NO DATA USE.	WATER IS AN EXCELLENT REFLECTOR OF MICROWAVES AND, THEREFORE, WATER SURFACES SHOW AS A UNIFORM BLACK TONE ON RADAR IMAGERY. RADAR IMAGERY, THEREFORE, IS OF NO VALUE IN MEASURING PHYSICAL, OR CHEMICAL, OR BIOLOGICAL CHARACTERISTICS OF WATER. NO DATA USE.

HYDROLOGIC PROBLEM AREAS

MAPPING AND DESCRIPTION OF GROUND-WATER FEATURES	SNOW SURVEYING AND MAPPING
HIGHLY USEFUL FOR GEOLOGIC MAPPING, DRAINAGE MAPPING, AND IDENTIFICATION OF VEGETATION FEATURES ASSOCIATED WITH GROUND WATER. LARGE DATA USE.	USEFUL FOR MAPPING SNOW-COVERED AREAS. MODERATE DATA USE.
MAY BE USEFUL BUT PERHAPS NOT SUPERIOR TO PANCHROMATIC PHOTOGRAPHY. SMALL DATA USE.	MAY BE USEFUL BUT PERHAPS NOT SUPERIOR TO PANCHROMATIC PHOTOGRAPHY. SMALL DATA USE.
VALUABLE AS AN ADJUNCT TO PANCHROMATIC PHOTOGRAPHY BECAUSE SOME ROCK UNITS HAVE DIFFERENT CONTRASTS AND ARE, THEREFORE, MORE RECOGNIZABLE. MODERATE DATA USE.	NOT YET EVALUATED. SMALL DATA USE.
HIGH POTENTIAL FOR GEOLOGIC AND AQUIFER MAPPING AS AN ADJUNCT TO THE MORE READILY AVAILABLE STANDARD PANCHROMATIC PHOTOGRAPHY SMALL DATA USE.	MAY NOT BE SIGNIFICANTLY BETTER THAN PANCHROMATIC PHOTOGRAPHY. SMALL DATA USE.
PROBABLY SUPERIOR TO STANDARD COLOR PHOTOGGRAPHY IN DEFINING VEGETATION AND SOIL CHARACTERISTICS. SMALL DATA USE.	HAS BEEN USED TO DIFFERENTIATE NEW SNOW FROM ICE AND FIRN. SMALL DATA USE.
MAY BE HELPFUL IN MEASUREMENT OF SOIL MOISTURE AND GROUND-WATER DISCHARGE TO STREAMS BUT IS LESS HELPFUL THAN INFRARED IMAGERY BECAUSE OF THE SMALL AREA COVERED AND THE DIFFICULTY OF LOCATING THE TRACE OF THE RADIOMETER ON THE GROUND. SMALL DATA USE.	NOT EVALUATED FOR THIS PURPOSE. SMALL DATA USE.
NOW BEING EVALUATED AS A TOOL FOR LOCATING POINTS OF GROUND-WATER DISCHARGE TO STREAMS. SMALL DATA USE.	OF SOME USE IN SEA-ICE MAPPING BUT HAS NOT BEEN EVALUATED FOR USE IN SNOW SURVEYS FOR WATER-SUPPLY FORECASTING. SMALL DATA USE.
MODERATELY VALUABLE IN MAPPING GEOLOGIC STRUCTURE AND IN SOME LITHOLOGIC DIFFERENTIATION FOR GROUND-WATER EXPLORATION. SMALL DATA USE.	HAS SOME VALUE IN MAPPING SNOW-COVERED AREAS BUT DOES NOT GIVE DATA ON THE WATER CONTENT OF SNOW. SMALL DATA USE.

Table 1. -- EVALUATION OF REMOTE SENSORS AS HYDROLOGIC TOOLS (July 1966)

GLACIOLOGY	GEOMORPHOLOGY AND ASSESSMENT OF CHANGES IN THE HYDROLOGIC REGIMEN
MODERATE VALUE IN MAPPING SNOW AND ICE FIELDS AND SURFACE STRUCTURE OF GLACIERS. MODERATE DATA USE.	EXCELLENT FOR MEASUREMENT OF GEOMORPHIC PARAMETERS. SMALL-SCALE SPACE PHOTOGRAPHY ALLOWS SYNTHESIS OF LARGE FEATURES ON A REGIONAL BASIS. LARGE DATA USE.
MAY BE USEFUL BUT PROBABLY IS NOT SUPERIOR TO PANCHROMATIC PHOTOGRAPHY. SMALL DATA USE.	NOT YET EVALUATED FOR THIS PURPOSE.
NOW BEING EVALUATED. SMALL DATA USE.	HELPFUL IN ADDITION TO NORMAL AERIAL PHOTOGRAPHY BUT NOT NORMALLY USED ALONE. SMALL DATA USE.
HELPFUL IN DETECTION AND IDENTIFICATION OF TYPES OF ICE AND SNOW. SMALL DATA USE.	HELPFUL IN DETERMINATION OF TYPES AND COMPOSITION OF SURFICIAL DEPOSITS. SMALL DATA USE.
HAS BEEN USED TO DIFFERENTIATE NEW SNOW FROM ICE AND FIRN. SMALL DATA USE.	MAY BE SUPERIOR TO STANDARD PHOTOGRAPHY. SMALL DATA USE.
NOT EVALUATED FOR THIS PURPOSE. SMALL DATA USE.	PROBABLY NOT USEFUL FOR THIS PURPOSE. SMALL DATA USE.
HELPFUL IN MAPPING ICE AND SNOW TEMPERATURE AND STATE. SMALL DATA USE.	NOT YET EVALUATED. SMALL DATA USE.
NOW BEING EVALUATED. SMALL DATA USE.	NOW BEING EVALUATED. SMALL DATA USE.

MEASUREMENT OF LIQUID-VAPOR TRANSFER IN THE HYDROLOGIC CYCLE	GENERAL COMMENTS ON POTENTIAL VALUE AND USE OF REMOTE-SENSOR SYSTEM FOR HYDROLOGIC STUDIES
NOT APPLICABLE TO THIS PROBLEM.	PANCHROMATIC PHOTOGRAPHY IS THE MOST WIDELY USED REMOTE-SENSING TECHNIQUE BECAUSE OF ITS AVAILABILITY AND RELATIVELY LOW COST. INTERPRETIVE TECHNIQUES ARE WELL DEVELOPED AND FORMAL TRAINING IN ITS USE IS AVAILABLE.
NOT APPLICABLE TO THIS PROBLEM.	MULTISPECTRAL PHOTOGRAPHY INTERPRETATION REQUIRES A BACKGROUND OF SPECTRAL-SIGNATURE STUDIES OF TERRAIN AND WATER FEATURES THAT HAVE NOT YET BEEN MADE. DATA RETURNS FROM MULTISPECTRAL SYSTEMS MAY BE SO VOLUMINOUS THAT THEY CANNOT BE READILY INTERPRETED. LITTLE WORK HAS BEEN DONE ON INTERPRETATION FOR HYDROLOGIC PURPOSES.
NOT APPLICABLE TO THIS PROBLEM.	INFRARED PHOTOGRAPHY IS PRIMARILY OF VALUE IN MAPPING DRAINAGE FEATURES AND SHORELINES. THE WATER IS ALWAYS BLACK IN A POSITIVE PRINT. SOME VEGETATION CHARACTERISTICS ARE DISCERNIBLE. ITS MOST VALUABLE USE IS AS AN ADJUNCT TO, BUT NOT A REPLACEMENT FOR, STANDARD AERIAL PHOTOGRAPHY.
NOT APPLICABLE TO THIS PROBLEM.	COLOR PHOTOGRAPHY, IN SPITE OF ITS BUILT-IN SPECTRAL REDUNDANCY, PROMISES TO BE A MAJOR TOOL OF THE HYDROLOGIST IN MANY SPECIAL FIELDS AND IS SUFFICIENTLY BETTER FOR RECOGNITION OF SIGNIFICANT HYDROLOGIC FEATURES THAT IT MAY REPLACE PANCHROMATIC PHOTOGRAPHY FOR MANY USES. THE INTERPRETATION CAPABILITY OF THE POTENTIAL OPERATIONAL HYDROLOGIC USERS OF COLOR PHOTOGRAPHY MUST BE GREATLY INCREASED.
NOT APPLICABLE TO THIS PROBLEM.	COLOR-INFRARED PHOTOGRAPHY MAY BE SUPERIOR TO STANDARD COLOR PHOTOGRAPHY IN SOME RESPECTS. IT SHOWS DIFFERENCES IN VEGETATION MORE CLEARLY AND PROVIDES A SLIGHTLY HIGHER CONTRAST ON WATER SURFACES. ITS GENERAL SUPERIORITY TO STANDARD COLOR PHOTOGRAPHY HAS YET TO BE PROVED BUT IT MAY BE HIGHLY USEFUL AND IS WORTHY OF MUCH ADDITIONAL RESEARCH.
HELPFUL IN DETERMINING RADIATIVE TRANSFER OF ENERGY FROM WATER AND LAND SURFACES TO THE ATMOSPHERE. SMALL DATA USE	INFRARED RADIOMETRY IS VERY USEFUL FOR SEQUENTIAL MEASUREMENTS OF CHANGES IN LAND AND WATER SURFACE TEMPERATURES BECAUSE IT IS A SIMPLE MEASUREMENT TECHNIQUE AND DATA REDUCTION IS SIMPLER THAN FOR INFRARED IMAGERY. RADIOMETRY IS ROUTINELY USED FOR PERIODIC SURVEYS OF NEAR-SHORE OCEANIC AREAS.
USEFUL IN REGIONAL ATMOSPHERIC PHYSICS BUT NOT USED IN SMALL-SCALE STUDIES. SMALL DATA USE.	INFRARED IMAGERY HAS SHOWN ITS VALUE AS A TOOL FOR MEASURING WATER-SURFACE TEMPERATURE AND AS A MEANS OF QUALITATIVELY DIFFERENTIATING SOME TERRESTRIAL FEATURES. THE LACK OF A SIMPLE MEANS OF DETERMINING EMISSIVITY HAMPERS ITS QUANTITATIVE USEFULNESS. ANALYTICAL TECHNIQUES FOR PROPER USE OF THE REDUCED DATA NEED TO BE DEVELOPED.
NOT APPLICABLE TO THIS PROBLEM.	RADAR IMAGERY IS AN EXCELLENT TOOL FOR ALL-WEATHER COVERAGE OF LARGE AREAS. IT IS OF MODERATE USE IN MAPPING STRUCTURAL FEATURES AND OF SOME USE IN DIFFERENTIATING SOME ROCK TYPES. IT IS QUITE USABLE FOR SMALL-SCALE PLANIMETRIC MAPPING WHERE NO BETTER MAPS ARE AVAILABLE.